Observations on Seasonality and Mortality from a Recent Catastrophic Death Assemblage

Patrick M. Lubinski

Department of Anthropology, Central Washington University, Ellensburg, WA 98926-7544, U.S.A.

Christopher J. O'Brien

Mountain Heritage Associates, USDA Forest Service, 55 South Sacramento Street, Susanville, CA 96130, U.S.A.

On 3 November 1991, a group of 150 pronghorn went over a cliff near Green River, Wyoming. This mortality site provides a unique opportunity to examine a number of characteristics of catastrophic death assemblages that may aid in the interpretation of archaeological bonebed sites. In 1993, the mandibles were collected for a study of seasonality and age estimation. Examination of seasonality revealed some variation in estimates by eruption/wear and cementum increments. Six percent of 86 fawn specimens exhibit eruption and wear more advanced than expected for a November third event, and 21% of 28 cementum increment estimates differ from the known November third mortality date by a month or more. These data suggest some degree of error is inherent in seasonality estimates that must be considered when interpreting seasonal distributions. Age estimates by eruption and wear reveal a distribution of pronghorn ages with many more juvenile animals than expected for a known "catastrophic" event. This may be explained by the pattern of seasonal hunting in a modern managed herd, which is likely to be very different than aboriginal hunting patterns. Age estimates by eruption/wear and cementum increment techniques failed to agree within six months in 48% of 29 test cases, with a tendency for cementum ages to be younger in 71% of specimens in which estimates of age differed. In general, the mandible assemblage exhibited more variability than one might expect for a single catastrophic kill event.

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Introduction

On 3 November 1991, 150 pronghorn (*Antilocapra americana* Ord) went over a cliff in Reiser Canyon, near Green River, Wyoming (Ottman, 1992). All animals perished on that day, except for a few wounded animals that were put down the following day by the Wyoming Game and Fish Department. The site has been left nearly undisturbed, and presents an unparalleled opportunity to examine a number of issues in age methods, mortality profiles, seasonality, and the taphonomic history of bonebed formation. In this paper, we will address a few of these issues related to age determination and seasonality.

This research was initiated to apply to the evaluation of several archaeological pronghorn bonebed sites thought to represent mass kill events in southwest Wyoming (Lubinski, 1997). Major questions to be addressed with the Reiser Canyon assemblage included: (1) How much variation in seasonality estimates can be expected for animals that died in one event? (2) Can age class cohorts be distinguished on the

basis of eruption and wear methods? (3) What does the mortality profile look like, and how does the age determination method affect the profile? By addressing these questions and making other observations on the Reiser Canyon assemblage, we expect to provide information for more rigorous interpretations of archaeological bonebed assemblages. Towards this end, the senior author collected all mandibles from the Reiser Canyon jump in order to evaluate methods and interpretations of mortality patterns and seasonality estimates.

The Reiser Canyon Mortality Site

The mortality site is located within an area of high bluffs, rolling hills, and canyons that characterize the dissected uplands adjacent to the Green River in southwest Wyoming. The pronghorn apparently went over this cliff, hit a small ledge below it, and came to a rest on the talus slope at the base of the cliff. The carcasses were distributed in a large central pile and

Figure 1. View of main carcass concentration in 1991 from small ledge just upslope of it.

Figure 2. View of main bone concentration in 1993 from small ledge just upslope of it. Compare to Figure 1.

nearby smaller piles, with a few animals scattered along the canyon floor up to 100 metres or more from the pile. It is not known why the animals went over the cliff—there were no tracks of predators or humans—but several factors may be relevant: (1) there was a very dense fog that day, (2) the top of the cliff slopes gradually, so that the precipice is difficult to see until it is too late, and (3) this herd probably was on its migration to winter range, and may have been unfamiliar with the area. In any case, 150 animals died here on 3–4 November 1991. Shortly after the event, biologists from the Wyoming Game and Fish Department and archaeologists from Western Wyoming College counted the animals, recorded sex and estimated age, took photos (e.g., Figure 1) and made a map of the site. The site then was left undisturbed except by scavengers and the occasional trophy collector or tourist. Scavengers of the pronghorn might have included domestic dogs as well as wild animals.

In September 1993, nearly two years after the event, the senior author first visited the site. Figure 2 shows the condition of the site in 1993 from the same location as Figure 1. Both view the "main pile" from the small

ledge, with the cliff behind the camera. The site was at this time characterized by widely scattered bones, and a few dense mats of pronghorn hair, partially articulated skeletons, and bone fragments, often surrounded by a thick growth of halogeton (*Halogeton glomeratus*). The larger of these hair mats were tightly packed, up to 10 cm thick, covered with insect casings, and provided good protection for bones within them. A portion of the main bone pile had been covered by sediment up to 20 cm thick from a badger burrow just upslope of the pile.

All observed mandibles were mapped and collected, taking care to disturb the remaining bones as little as possible. The September 1993 collection yielded 244 mandibles or mandible fragments out of an expected 300 mandibles from the 150 animals that died there. Clearly, some specimens had been destroyed or were not visible. A return trip in June 1995 yielded an additional 13 specimens from the main pile and vicinity. All of these specimens are assumed to be a product of the 1991 cliff jump with the exception of a single heavily weathered specimen recovered in 1993. In total, 256 specimens were recovered, which account for a minimum of 242 complete mandibles (MNE) and a minimum of 121 animals (MNI) based upon the 121 left permanent P4 crypts and 121 right M2 sockets in the sample. About 60% of specimens ($N=158$) were recovered in the main pile, but 23 specimens (9%) were more than 50 m away. Only 45 specimens (18%) still were articulated with a cranium, while 20 (8%) were completely isolated from any other bones (besides the matching mandible half). The lack of cranial articulations in the main pile may be the result of skulls rolling down the slope as the connective tissue with the remaining skeleton disintegrated.

Condition of the Collected Assemblage

The recovered mandibles were in fair to excellent condition. About half of the specimens were found fully exposed on the surface, a quarter were completely buried in hair mat, and a quarter were partially buried. Those recovered from exposed contexts generally exhibited bleaching, some weathering, and moderate to extensive fracturing of the teeth. As noted previously by Toots (1965), the teeth appear to disintegrate much more rapidly than the mandibular bone. Mandibles that were recovered within the hair mats generally exhibited less weathering and tooth fracture, and some of these specimens were stained brown.

Carnivore modification was observed on relatively few specimens, which might be expected given the large amount of available meat and bones at the site, and the relatively low desirability of mandibles compared to other elements (Binford, 1978: 31). Only 10 specimens exhibited unambiguous evidence of carnivore damage, such as tooth punctures, scoring, or scalloped, crenelated edges. An additional five specimens

Table 1. Reiser Canyon 1993 mandible weathering distribution

| | Maximum Weathering Stage | | | | | | | |
	0	1	2	3	4	5	Not recorded	Total
Specimens	21	109	94	8	0	0	11	243
Percent	9	45	39	3	0	0	5	101

exhibited more ambiguous indicators such as minor edge damage on the angle, or irregular punctures without associated scoring. Together, specimens with possible carnivore modification account for only 6% of the Reiser Canyon assemblage. Most of these specimens were found far from the main pile. In fact, nearly half (46% of 24) of the specimens found more than 50 m from the main pile exhibited probable carnivore modification, as opposed to only 2% (3/158) of the mandibles in the main pile. This seems to indicate that carnivores preferred to gnaw on the relatively isolated carcasses and/or dragged mandibles to locations remote from the main pile.

As might be expected for an assemblage exposed about 2 years, the mandibles exhibited a range of weathering from none to moderate. Specimens were assigned a weathering stage from zero to five (stages after Lyman & Fox (1989: 294)) based on their most weathered surface. The weathering distribution of specimens collected in 1993 is given in Table 1. The variability in weathering is partly due to differential coverage by hair and other material, because 90% of specimens in hair mats are lightly weathered (stage 0 or 1), but less than half (44%) of fully exposed specimens exhibit light weathering. However, the variation in weathering is not explained solely by differential burial, because nearly half (46%) of the lightly weathered specimens were found completely exposed. The remaining variation probably is due to other differences in setting, such as vegetation and topographic setting.

Disarticulation and movement of the mandibles probably accounts for some additional variation in weathering. In other words, some bones appear to have moved from protected contexts to exposed contexts. Specimens exhibiting waxy surfaces on both lingual and buccal sides seem unlikely in exposed contexts, yet 20% of such unweathered specimens are from exposed contexts. Additionally, a small number (8%) of mandibles with brown surface staining on both sides were recovered on the open surface.

Methods

Age and season of death estimates were made on the mandible assemblage using both tooth eruption/wear and dental cementum increment methods. The primary goals of the age study were to examine the age

distribution of a known catastrophic event and compare results of the two methods of age estimation. The primary goal of the seasonality study was to determine how much variability in estimates was obtained for a known date of mortality.

Eruption/wear methods
Eruption/wear age and seasonality estimates were made on all mandible specimens by the senior author. Each cusp of each erupting tooth was scored for eruption in one of seven stages: (Z) crypt closed; (C) crypt open but cusp not visible; (V) cusp visible below alveolar surface; (1) cusp 1/4 erupted; (2) cusp 1/2 erupted; (3) cusp 3/4 erupted; and (4) cusp fully erupted. Increments of full eruption were determined by scaling the measured height of the cusp to an adjacent, fully erupted cusp. Measurements were made with sliding vernier calipers to the nearest 0·1 mm. Each tooth was scored for wear pattern using a new scoring system (Lubinski, 2001a) similar to those described by Payne (1987) and Brown & Chapman (1990), where a score increases as each occlusal facet comes into dentine wear or infundibulum is lost.

Age estimates were made by comparing the eruption and wear scores with schedules derived by the senior author from a sample of about 50 known age and 200 known date-of-mortality pronghorn mandibles, supplemented by additional published known-age specimens (Dow & Wright, 1962; Hoover, Till & Oglivie, 1959). The scoring methods and eruption/wear schedules are described in detail elsewhere (Lubinski, 2001a), but generally speaking, pronghorn age can be estimated easily with juveniles, but a good deal of uncertainty is involved with mature animals due to the lack of adequate known-age samples. Even when a Reiser Canyon mandible exhibits wear matching a known-age specimen, it is by no means certain that it is the same age given the potential differences in rates of wear between individuals and between populations in different habitats. Reiser Canyon mandibles with wear intermediate between known-age animals present a greater interpretive problem. For these reasons, Reiser Canyon mandibles were sorted into wear groups roughly corresponding with the known age mandibles, but it is understood that the wear group may not be equivalent in age to the corresponding known-age mandibles.

Eruption/wear season of death estimates were made on all fawn specimens by estimating animal age to the tenth of a year and adding this age to an assumed birthdate of 1 June ± 2 weeks. The assumption of 1 June birthdate is a slight oversimplification of pronghorn birth patterns, but studies show pronghorn have a mean birthdate in early June, and a total fawning season of only 7 to 24 days (Fairbanks, 1993; Hoover, Till & Oglivie, 1959: 35–37; Mitchell, 1967). By this method, an animal 0·4 years old would have died between late September and late November.

Cementum increment methods

Cementum increment age and seasonality estimates were made by the junior author on a small sample of first molar (M1) teeth. This was a blind test in which he received the tooth specimens without any knowledge of their provenience, and was informed only that there might well be several ages and seasons represented in the sample. Methods of sample preparation and analysis followed those standardized by increment researchers in recent years (see detailed discussions in Lieberman, 1994; Lieberman, Deacon & Meadow, 1990; Lieberman & Meadow, 1992; see also Burke & Castanet, 1995; O'Brien, 1994; Pike-Tay, 1991, 1995). Teeth were embedded in epoxy and sectioned in the bucco-lingual plane using a slow-speed diamond saw. Thin sections were mounted onto glass slides, then ground and polished until sufficiently thin that histological features such as dentine tubules could be readily identified (Lieberman, 1994). Sections were examined on a computer video monitor linked to a transmitted, polarized light microscope under a magnification of $100–125 \times$.

Cementum increments were analysed in the area of acellular cementum apposition just apical to the dentin-enamel junction. On high crowned ungulates like pronghorn, cementum apposition also occurs along a significant portion of the enamel, but increments are less regular here. Lieberman (1993, 1994; Lieberman & Meadow, 1992) has shown that acellular cementum increments grow at a relatively slow and constant rate and are useful for determining both age and season of death. Comparative analyses of acellular cementum increments in ungulates with known dates of death substantiates this observation (O'Brien, 1994, 2001; Pike-Tay, 1991, 1995).

Season of death estimates were made by visual estimation of the percent completion of the outermost increment. The appearance of the outermost increment (either opaque (dark) or translucent (light)) was noted and its width relative to previously deposited increments was determined. Percent completion was estimated for the outermost increment to the nearest 25% of growth (i.e., 25% complete, 50% complete, etc.). Increment completion estimates are most easily determined for "growth" (translucent) increments, which are wider than non-growth (opaque) increments. We assume a constant rate of cementum formation within each increment type (opaque or translucent). Although Lieberman (1993, 1994) has demonstrated that overall intra-increment formation rates differ between opaque and translucent increments, formation rates within either increment type are relatively constant. Using a large sample of known date-of-death caribou (*Rangifer tarandus*), Pike-Tay (1995) showed that translucent increment deposition is slightly slower at the beginning of the growth season but achieves a constant rate of formation very quickly. We assume the translucent

increment forms from May to October and the opaque increment from November to April by analogy to other temperate latitude ungulates (Burke & Castanet, 1995; Leigh, 1998; Pike-Tay *et al.*, 1999).

Determining age at death from increment data requires a different set of assumptions and knowledge than those used for determining season of death (O'Brien, 1994). Although a count of the total number of increments will yield an age in years, this value may not reflect the full life history of the individual. An increment count will be inaccurate unless it takes into account the age at which the examined tooth erupts, because cementum appears to begin forming on the roots just prior to occlusal wear (Pike-Tay, 1991). The following formula was used to estimate age to the nearest six months: base age + age at first opaque increment + outer increment age. Base age is the time represented by the number of opaque increments minus one. Since cementum deposits between each opaque increment represent one year's growth, an individual with five opaque increments has a total of four years represented between the first and last opaque increment, or a base age of four. The age at first opaque increment takes into account the time between birth and formation of the first opaque increment on the examined tooth. This age for a pronghorn first molar (M1) is about six months (0·5 years), since there are about six months between the animal's birth and first winter, and the M1 erupts before the first winter. The outer increment age takes into account the time between the formation of the last opaque increment and death by considering the outer increment growth stage in relation to average date of birth and formation of the opaque and translucent increments. In the case of pronghorn, an additional 0·5 years are added if the outer increment is translucent (representing animals killed 0–6 months after their June birthday), and nothing is added if the outer increment is opaque. Thus an animal with five opaque increments and an outer, partially completed translucent increment would have an estimated age of 5·0 years. In some cases, the number of increments was unclear and estimates were given as a range of years.

Season Estimate Results

Eruption/wear season estimates were made on 86 Reiser Canyon fawn specimens. We know that Reiser Canyon fawns are 0·4 years old, but in this blind test the mandibles exhibited eruption and wear scores that overlapped several age classes. Specimens exhibited eruption and wear greater than the September comparative fawns (0·3 year olds), overlapping the range exhibited by December fawns (0·5 year olds), and partially overlapping with the February fawns (0·7 year olds). (There are no comparative November (0·4) or January (0·6) fawns.) The vast majority (81, 94%) of
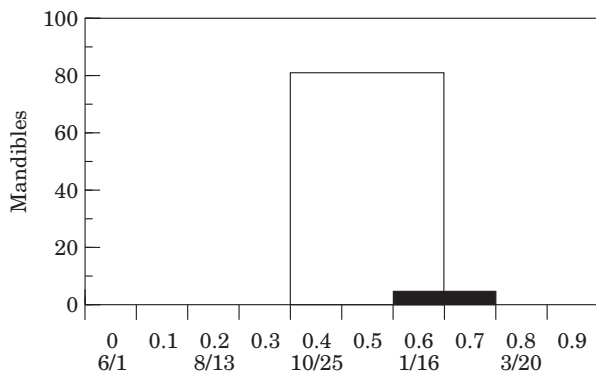
Figure 3. Seasonality estimates from fawn eruption and wear. X-axis indicates age estimate (tenths of a year) and corresponding season estimate.
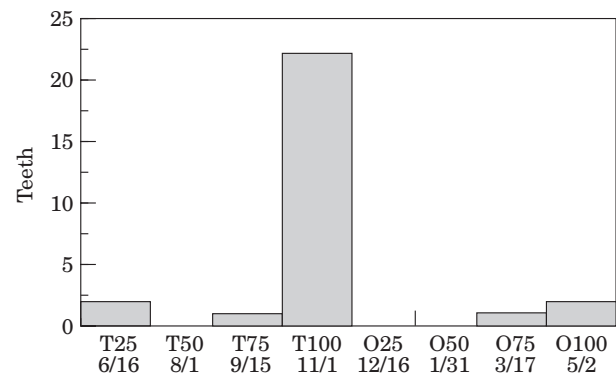

Figure 4. Seasonality estimates from cementum increment analysis. X-axis indicates estimate on outer increment completion and corresponding season estimate. Data from Table 2.

Table 2. Cementum increments and season of death estimates

Increment	% Completion	Corresponding estimate	N
Translucent	25	June 16	2
	50	August 1	0
	75	September 15	1
	100	November 1	22
Opaque	25	December 16	0
	50	January 31	0
	75	March 17	1
	100	May 2	2

the 86 fawn specimens match 0·4 to 0·6 year olds, and provide a season estimate of early October to late January, but the remaining 6% of specimens match 0·6 to 0·7 year olds and provide an estimate of late December to mid February (Figure 3). This indicates that 6% of the fawn eruption and wear season estimates are inconsistent with the known date of death on 3–4 November. Even the specimens that are consistent with a November kill provide coarse estimates of season on the order of 3/10 of a year.

Cementum increment season of death estimates were obtained for 28 teeth. The estimates are not identical (Table 2). Although the majority (22/28; 79%) of the teeth showed a complete translucent outer increment, three (11%) showed a half-completed to full opaque outer increment, and the remaining three showed partially-completed translucent increments. If the translucent increment is completed in October and the opaque increment begins to form in November, then 79% of the estimates are consistent with a November third mortality event. To estimate the spread of the remaining estimates, we have assumed the opaque increment begins forming 1 November, and one quarter of an increment is added every 1/8th of a year thereafter (Table 2). In this case, the distribution of season estimates would approximate the histogram in Figure 4.

Season Estimate Discussion

Both eruption/wear and cementum increment techniques yielded variation in season of death estimates for a mortality event known to take place 3–4 November 1991. In both cases, the majority of estimates are consistent with a November kill, but a proportion of estimates are inconsistent with the known date of mortality. Possible causes of the variation in season estimates vary by method.

The variation in eruption/wear season estimates may be due to out-of-season birthdates, variable rates of eruption and wear, and inadequacies of the comparative samples. A plausible explanation is that the sagebrush country Reiser Canyon animals experienced a faster rate of tooth wear than the comparative mandibles which primarily derive from the grasslands of Montana. Whatever the reasons, some degree of variation (about 6% with the fawns used here) can be expected even for animals that died at the same time. The variation in season estimates observed here could be significantly reduced if more comparative mandibles were available, and the inclusion of Reiser Canyon mandibles in Lubinski's (2001a) eruption and wear schedules significantly reduces uncertainty for fall pronghorn kills.

The reasons for the lack of consistency in cementum increment season estimates are unclear, but there are three major possibilities. First, it is possible that some of the out-of-season specimens were from animals not associated with the November cliff kill. This seems very unlikely since three of the out-of-phase specimens were partially buried in the main pile, two were within 2 m of the main pile, and the final specimen was associated with an articulated skeleton and hair mat about 20 m from the main pile. A second possibility is that some small degree of variation can be expected because increment formation is not occurring at a uniform rate. Although we assume that intra-increment formation rates are constant, the data are not conclusive. Based on analysis of mountain gazelle (*Gazella gazella*), Lieberman (1994) indicates that formation is relatively

uniform within each increment type. Pike-Tay (1995), using known date-of-death caribou (*Rangifer tarandus*), suggests that formation rates for the translucent increment are initially slow but become uniform very quickly. Spiess (1990) and Burke & Castanet (1995) indicate variable rates of growth zone (translucent increment) deposition in white-tailed deer (*Odocoileus virginianus*) and horse (*Equus caballus*). At a minimum, some inter-species variability in cementum deposition rates may be evident but the degree to which it may have affected interpretation of the pronghorn dental increments is uncertain.

A third possibility is observer error, including error in estimating the relative increment width and misidentification of the outer increment type. Misidentification of the outer increment may result from sediment adhering to the outer tooth surface, optical effects, and various processing errors (Lieberman, 1994). In a blind test conducted on 20 teeth from known date-of-death gazelle, Lieberman, Deacon & Meadow (1990) documented a mean misidentification error of 12·5% using estimates from two independent observers (individual errors were 10% and 15%). Our test resulted in a potential misidentification error of 11%, a rate consistent with these data. Other errors may be due to difficulties inherent in estimating relative increment width. Computer image enhancement and analysis, including empirical methods for determining increment width, may significantly reduce the probability of observer error (Lieberman, Deacon & Meadow, 1990; Lieberman, 1994; Pike-Tay, 1995). Systematic tests for reliability (including comparisons between observers, sections, teeth, individuals, etc. (see Pike-Tay, 1995 and Lieberman, Deacon & Meadow, 1990 for initial work) will help establish sources of error and methods for minimizing them in future research.

Rather than trying to explain away the variation, we propose that some degree of error can be expected when cementum increments are used to estimate season in the way we did here. If this sample can be used as a model, the expected error, assuming a constant rate of cementum formation, would be about 21% (6/28) for an estimate of ±1 month, 18% (5/28) for an estimate of ±2 months, and 14% (4/28) for an estimate of ±3 months. Uneven seasonal rates of cementum formation would significantly change these values.

These findings have two major implications for the interpretation of season estimates from archaeological specimens. The first is that rare, outlying season estimates should be interpreted cautiously because some variability or ''observational error'' is inherent in seasonality estimates. Conversely, the variability in season estimates makes it difficult to demonstrate uniform seasonality, a necessary but not sufficient requirement for the demonstration of mass kills. While we cannot demonstrate that animals all died on the same day, we can judge whether a given seasonal distribution is consistent or inconsistent with a single mortality event. If we use the Reiser Canyon blind season estimates as a crude model, about 94% or more of eruption/wear season estimates should exhibit a uniform season estimate with a range of 3/10 of a year or less, and about 79% or more of cementum increment season estimates should fall within a 2 month period in order to be consistent with a single kill event.

Age Determination Results

Eruption/wear age estimates were made on 218 specimens representing a minimum of 113 individual pronghorn. When placed into wear age groups assumed to correspond with annual cohorts, the Reiser Canyon assemblage provides an age distribution of 46 fawns, 36 yearlings, six 2-year-olds, 11 3-year-olds, eight 4-year-olds, two 5-year-olds, and four individuals 6 or more years old.

Cementum increment age estimates were obtained for 29 mature pronghorn teeth. These estimates ranged from two to five years old, while the same teeth provided estimates of two to seven years old based on eruption and wear. Figure 5 shows the distribution of age estimates for the 16 teeth which had single year estimates for both cementum and wear. Of all specimens, including those with a range of estimates, only 52% overlapped or agreed within a half a year. When age estimates differed, the increment age was less than wear age in 71% of cases.

Age Determination Discussion

Age determinations have often been obtained for archaeological faunas to distinguish between mass mortality, such as expected for large communal hunts, and accumulations of single mortality events, such as expected for palimpsests of small hunting events (e.g., Klein, 1978; Levine, 1983; Reher, 1970; Stiner, 1991). To do this, archaeologists generally have borrowed a pair of theoretical mortality models from paleobiologists (e.g., Kurtén, 1953; Voorhies, 1969) termed ''catastrophic'' mortality (wherein the prey age structure was expected to represent a normal living population as if frozen at one instant of time) and ''attritional'' mortality (wherein the prey age structure was expected to represent the slow accumulation of natural mortality from a normal living population). Large cooperative kills are expected to result in a random selection of animal ages so that the mortality profile approximates the age structure of a living population (a catastrophic profile). Catastrophic age profiles are expected to be roughly triangular (with many young and progressively fewer older individuals), while attritional age profiles are expected to be U-shaped (peaks in the youngest and oldest age classes) or L-shaped (juvenile dominated), depending on the actual rate of mortality of different age classes (e.g., Klein, 1987). The Reiser Canyon age profile was
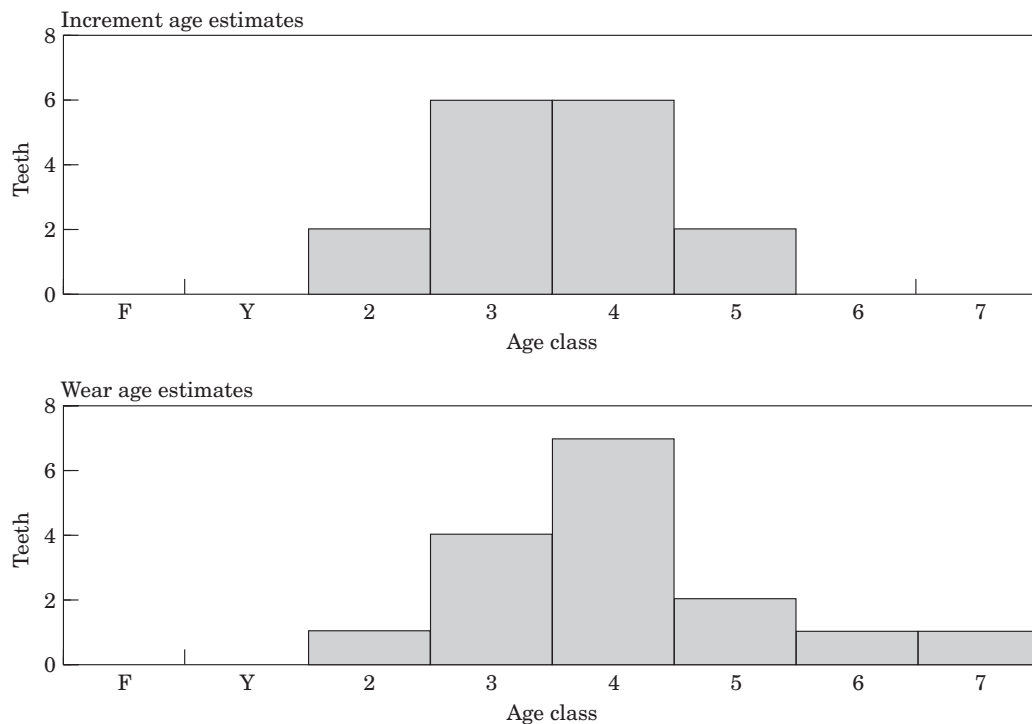
Figure 5. Comparison of age estimates.

naturally expected to be catastrophic since the event reportedly involved an entire herd falling to its death over a cliff.

Eruption/wear age estimates

Despite these expectations, the Reiser Canyon eruption/wear age distribution has many more fawns and yearlings than expected for a normal living population. As shown in Figure 6, the Reiser Canyon age distribution differs significantly from the regional herd age distribution for the same season as modelled using Wyoming Game and Fish Department census data. It is not known why the Reiser Canyon assemblage exhibits an age distribution unlike the expected catastrophic age distribution. It is possible that the age distribution is the result of strong hunting pressure due to a herd-reduction strategy at that time (Christiansen, pers. comm.), or that the entire herd did not go over the cliff (Ottman, 1992). Despite its unexpected nature, the Reiser Canyon distribution may be exactly what we should expect for a population subject to heavy, seasonally-restricted hunting. After all, the cliff jump occurred shortly after the hunting season which probably removed a significant portion of the prime-aged animals from the herd.

This hypothesis was tested by simulating heavy hunting pressure (50%) on the fall 1991 living model by "subtracting" the expected hunting age distribution from the fall 1991 living distribution. If half of the fall Reiser Canyon herd was killed during the September-October hunting season, the resulting November distribution would appear as in Figure 6.

Although the hypothetical November 1991 distribution and Reiser Canyon (November 1991) distribution in Figure 6 are not identical, they are quite similar. Using the Kolmogorov–Smirnov (K–S) test to compare them (model sample size set equal to Reiser Canyon sample), there is no apparent difference at the 0·05 level of significance (max P.D. = 10%, K–S = 0·75). [Compare this to a significant difference at 0·001 level (max P.D. = 29%, K–S = 2·20) for a test involving Reiser Canyon and the 1991 fall living model.]

The "unexpected" nature of the Reiser Canyon age distribution points out the marked seasonal differences in population profiles from heavily hunted and intensively managed modern herds. While it probably would be unwise to assume that the Reiser Canyon profile is representative of a normal prehistoric pronghorn herd, we do not know for certain what a normal prehistoric herd should look like under prehistoric patterns of hunting. Seasonally restricted and age selective individual hunts like those today are unlikely for the past but year-round prime-dominated individual hunts are very plausible. Under this hunting pattern, it is quite possible that living pronghorn herds would tend to be somewhat L-shaped or U-shaped compared to the stereotypical triangular living profile. In this case, mass kills might provide age profiles
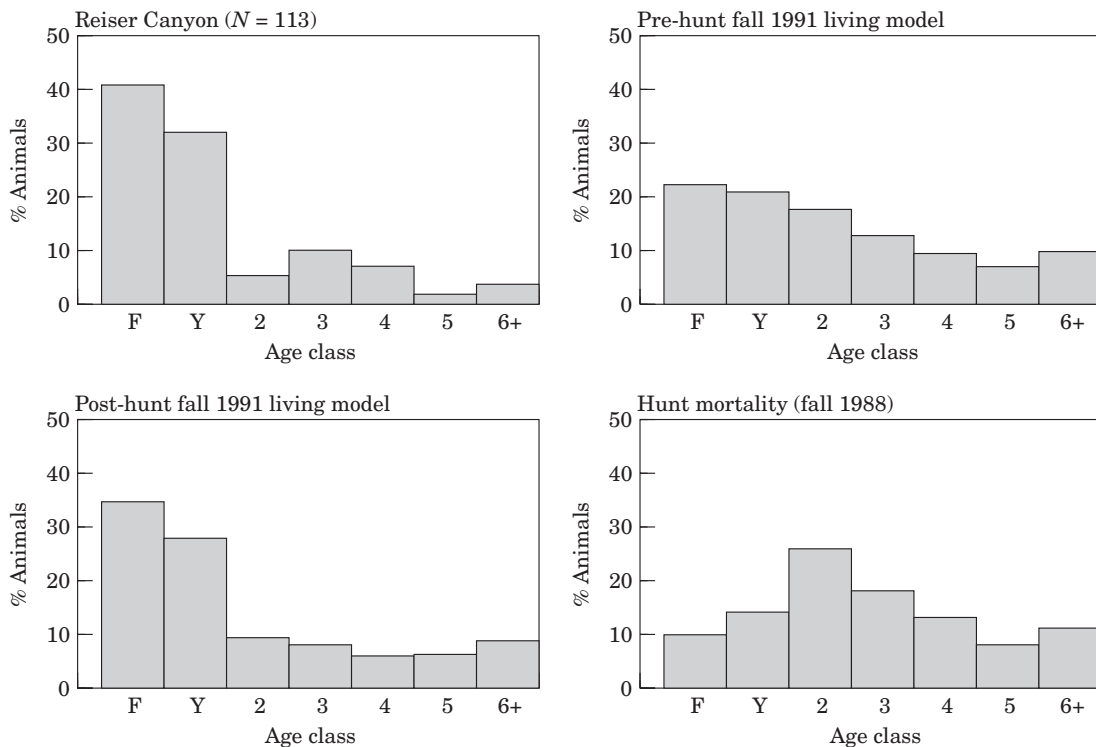
Figure 6. Reiser Canyon mortality profile and hypothetical post-hunt age profiles. (Upper Left) Estimated Reiser Canyon distribution as found in this study. (Upper Right) pre-hunt fall 1991 regional herd distribution, based on Wyoming Game and Fish model and pre-season mortality rates (Christiansen, 1996). (Lower Left) hypothetical post-hunt fall 1991 age distribution generated by simulating 50% reduction of pre-hunt herd. (Lower Right) 1988 fall harvest age distribution used to generate lower left distribution (Christiansen, 1989: Table 2).

somewhat between modern pre-hunting season living profiles and U-shaped profiles.

Although the implications of these findings can be debated, the age profile at Reiser Canyon clearly provokes questions about the use of idealized mortality profiles (see also Lubinski, 2001b). If the Reiser Canyon profile and attritional profiles are at all similar, then there would appear to be less difference between real catastrophic and attritional mortality than expected from idealized models.

Cementum increment age estimates

Age estimates by cementum increment methods were made on a small sample of the Reiser Canyon assemblage, so no direct comparison of resulting age distributions can be made. Instead, eruption/wear and cementum increment age estimates are compared with the understanding that differences in the estimates may provide different overall mortality distributions. If the cementum increment sample examined here is representative (with a tendency for younger estimates than those based on wear data), a mortality profile employing increment ages would appear different than the profile shown earlier, possibly with a more uniform triangular shape and a more rapid dropoff to zero at the old end.

If the increment ages largely are correct, this could mean that wear methods tend to overestimate age, possibly because wear in the southwest Wyoming herd occurs at a faster rate than expected based on the known-age specimens from the grasslands of Montana. Although this is quite possible, we simply do not know if the cementum ages are correct without a test against known-age specimens. For this reason, we did not attempt to calibrate the older wear groups with cementum increment ages. The calibration approach may be overly optimistic. In any event, there is a serious divergence that needs to be resolved before much confidence can be placed at least in the mature animal tooth wear age estimates. An alternative aging classification like a juvenile-prime-old system (Stiner, 1990) or fawn-yearling-mature system (Lubinski, 2001b) may avoid these difficulties, although these systems provide far more coarse data.

Conclusion

Reiser Canyon provides us an opportunity to examine some features of bonebed formation and some methodological issues not easily resolved with archaeological data alone. This discussion has barely scratched the surface of things we could learn from the site.

Although we have presented an abundance of data that seem to complicate the interpretation of pronghorn bonebed sites, we did not intend for this to be just another taphonomic cautionary tale. Instead, we hope that by demonstrating a wider degree of variability for a single mortality event than one might expect, we have called attention to the observational error inherent in our procedures. Methodological refinements may *reduce* the degree of inherent variability, but we would suggest that a certain degree of variability and error is unavoidable.

Assuming that this is true, the smallest observable range of variation consistent with a mass kill may be too broad to exclude other possibilities. For example, if our data are reliable and 6–21% of season estimates really are incorrect in an assemblage with the same date of death, then it becomes impossible to distinguish between one uniform kill season and a primary season plus some scatter. In such a case, consideration of additional lines of evidence is critical. Additional lines of evidence could include artifact associations, butchery information, topographic and geomorphic setting, and bone weathering patterns. It is likely that no one line of evidence can provide unambiguous results, and the interpretation is stronger when multiple criteria are considered.

Acknowledgements

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